

LABORATORY

♦ ♦ ♦ ♦ NOTES

Caldwell & Fish ♦ ♦ ♦ ♦

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NOTES AND QUESTIONS

FOR THE

DYNAMO LABORATORY

✓ BY

F. C. CALDWELL

"AND

F. A. FISH

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PREFACE.

The use of these "Notes and Questions" involves to a greater or less degree a system of laboratory instruction. While it may be claimed that the ideal method is that of the rediscovery by the student of the laws studied, it must be admitted that this is generally impracticable in engineering laboratories. Time for such a thorough system is usually wanting, and further, many who will make useful engineers have not, and never will have the talent of the discoverer. With such the method of rediscovery leads either to so much time being consumed with each piece of work, that too little ground is covered; or more usually, the student will get enough idea to go through with the experiment, and will then pass on to the next having no proper understanding of what he has done. On the other hand, if dependence is placed entirely upon a textbook giving full directions for carrying out the work, the less careful student will be satisfied when he has followed the instructions, regardless of how much or how little he has got out of them.

In view of these facts the accompanying scheme was devised for the purpose of obliging the student to thoroughly understand what he is doing. The method and most of the matter has been in use several years, and has worked so well that the authors venture to hope that in its published form it may prove useful to others.

CHAPTER I.

NOTES.

OBJECTS OF WORK IN DYNAMO LABORATORY.

IN ORDER OF IMPORTANCE.

1st. Facility in handling problems connected with dynamo machinery and engineering.

2nd. Judgment, accuracy, skill and quickness in performing laboratory operations.

3rd. Knowledge of particular facts and methods met with in the work.

ORDER OF OPERATION.

1st. Study thoroughly the work to be done; that is, be sure before beginning that what is sought and how it is to be obtained, is well understood. This will generally be accomplished by careful use of the questions and references.

2nd. Make, in note book, neat diagrams of all connections of machine and instruments used.

3rd. Make careful calibration of all instruments, but only through the range where readings are to be taken. If more convenient, this may be done at some other time during the test.

4th. Following the diagrams, set up and connect all apparatus to be used with as much speed as possible. The more active the part taken the more profit will be received from the work.

5th. Look over all connections again to be sure they are right, then try cautiously with the current.

6th. *Go over the whole course of the experiment as a preliminary run, taking only such readings as are necessary to*

show that everything is right. If anything is wrong, repeat the preliminary run till all is as it should be.

7th. Make the final runs, taking enough readings to get a good curve—generally about ten. The man whose instrument is most hard to read, or who is keeping a constant, should call, “Ready—Now,” and then give the number of the observation, all the other men entering their readings opposite the same number. If readings are unsteady, either take the average of three or five or let “Now” be called till every observer is sure of a good average reading. Always, if possible, take two runs.

8th. Immediately, if practicable, let each man read his figures for the others to note.

9th. Work up in company the results obtained, each man doing his share, and plot the curves. If not satisfactory, repeat.

In general where two or more are working together they should take turns in being responsible for the cool and proper running of the machinery used, including bearings, belts, commutators and windings. Anything, excepting sometimes a commutator, which is too hot to hold the hand on, is in a dangerous condition, and damages resulting, unless someone is ready to assume the blame, will be charged to all. Every man is personally responsible for returning to its place, in good condition every piece of apparatus and tool which he takes out, and if anything is out of order before or after use, it should be reported immediately.

GRADES.

Note book, curves and report blank must be handed in on the day set, and except in case of acceptable excuse, grade is discounted if reports are over due. Before the end of the term one blue print of each curve accepted must be handed in, to be filed for record. The grades depend upon completeness, accuracy and neatness in note book and curves, ability, quickness, carefulness, industry and freedom from “accidents” in the laboratory.

TOOLS.

Each student must provide himself with a small screw-driver and pair of pliers. A small wrench and a compass are also desirable. All tools should be marked with the owner's name, which may be done by etching with dilute nitric acid, using melted compound for protecting the metal, and writing while the latter is soft. It is also best for each student to be provided with about four *thumb-screw connectors.

All easily portable instruments must be replaced at the end of each day's work, and all other instruments, apparatus and machines disconnected and connecting cable and wires put away unless allowed to remain by special permission.

LABORATORY REPORTS.

To develop habits which will conform with the methods of practical work all notes, readings and results in connection with the laboratory work should be recorded as they are obtained and for permanent reference in a convenient and well made note book.†

This laboratory note book should have owner's name printed on slips of paper on the front cover, upper right hand corner and on the back, and the pages should be numbered. The books should be kept as clean and neat as possible, while always being used in the laboratory. Never make any notes whatever on pieces of paper or other note books. Do not crowd matter. Leave one or two sheets at the beginning and after each test. The readings should be entered directly, leaving necessary intermediate columns for corrected values and results. Put title on right hand page, and use several pages for description, answers to questions, sketches of connections, and all data of machine, test, etc., that may possibly be useful, including name, capacity, potential, speed, etc., of the

*These may well be supplied by the laboratory; see appendix.

*See Appendix.

machine, men working, and positions occupied by them, names and numbers of instruments, constants used, etc. Use conventional symbols as found on page 13 of Part II. In all diagrams, wiring should be represented by lines parallel with the edges of the page. At top of each page put name of test, date and reference to curves, etc. All columns should be carefully headed. These headings should include in each case the number of the instrument used. Make figures small and with pen or with pencil, neither too hard nor too soft. Always correct readings for errors of instruments. Refer to curves by number.

CURVES.

These may be either to show some property or peculiarity of the machine tested, or they may be for the purpose of comparing two instruments, as a calibrating curve of a voltmeter.

If for the former purpose the exact value of the scales chosen is of secondary importance, but the curves should be so drawn as to show to the best advantage the property which it is intended to bring out. They should usually incline in general direction about 45 degrees with the axes, and should not be too large; there is no advantage in taking more than one division of the paper to represent one division on the instrument read. The abscissæ should be the independent variable, the ordinates the dependent. The broad margin should be at the left or the top.

If for calibration use, the scale should also be chosen for convenient reading, i. e., 1 division equal 1-5, 1-4, 1-2, 1, 2, 4, or 5. Always give the scale, either on the margin or along the curve, and in whole numbers, not in observed values. Points should always be shown by circles, crosses, etc.: circles are best and should be made with a bow pen. In general as many curves as convenient dealing with one machine or set of tests should be placed together on one sheet. If they cross each other too much for clearness different linings or different colored inks

may be used. Always name each curve, or indicate it by letter or number reference. If several curves have one scale in common, put that on the margin, and the other scales along the curves, or in columns along the other margin. Put on each sheet all suitable data, including constants, name of student, date and reference to page of note book. Sometimes it is best to show a curve to two different scales to bring out different parts.

On printed report blanks, make out and hand in one report of each successful experiment, giving besides full data called for on blank, all readings taken and final results, i. e., those from which curve is plotted.

MEASURING INSTRUMENTS.

Always handle with the greatest care. Avoid jarring, as by setting down hard, dropping, moving a table with instruments on it, etc. Never use a magnetic instrument within five feet of a machine, or within one foot of other instruments or masses of iron. Never break a current at the terminals of an ammeter. In changing the terminals of a voltmeter, always change at the machine or circuit end.

In wiring up instruments, *always put wires through holes in table* provided for that purpose; or otherwise secure them so that it will be impossible to pull the instruments on to the floor. Avoid as much as possible crossing wires.

Remember: An ammeter has very low resistance. A voltmeter has very high resistance. *With low reading ammeters and possibility of higher currents always use fuse.* It is better to place a low reading ammeter where it can be short circuited, and then only open the circuit when ready to read.

CALIBRATION.

No instrument is ever absolutely correct except original standards, as standard meter in Paris, etc., and no quantitative results have commercial or scientific value, unless it is possible to trace back the standardization of the

instruments used to their original standards and to be sure of the comparison within a given per cent. of error. No ordinary electrical instruments, especially portables in common use, can be relied upon to keep their constants for any length of time. They should be compared with standard instruments at least once for every test; and, in case of importance, both before and after the test. To make comparison with other calibrations possible, readings should be taken for multiples of ten on the calibrated instrument, and properly recorded on blanks supplied for that purpose.

The profit that can be got from the laboratory work depends very largely upon the activity of the student himself. Every moment should be employed. If the conditions are such that nothing can be done on the experiment in hand progress may be made by working ahead on the questions for the next experiment. There is much more work that could be done than there is time for in the course; the most interesting is at the end, and how much of this the student gets depends largely upon himself.

CHAPTER II.

QUESTIONS ON DIRECT CURRENT LABORATORY EXPERIMENTS.

Before performing any experiment which has been assigned, study carefully the questions and references. Where references are not given, look up the subject in the text-books which are available. In some cases answers to part of the questions may better be deferred till after the experiment. Write the answers to the questions neatly in the note books without crowding, and leaving a line blank after each answer. For the earlier experiments very detailed questions are given, but later on the questions become more general, leaving to the student the exact form of the discussion, which however should be no less full.

1

CALIBRATION.

(a) Sketch connections for comparing with the standard, an ammeter having the same range. Also one having a different range.

(b) Same for a voltmeter.

(c) Given a 20 KW. 110 volt generator, with but three horse power available for running it, how can a 125 ampere ammeter be calibrated?

(d) Given a potential equal to the highest to be calibrated and a high resistance, all points of which are accessible, make a diagram of connections for calibrating a voltmeter from zero to its capacity.

(e) Make a diagram of all connections in the calibrating room.

2

STUDY OF RESISTANCE.

Examine resistances assigned, diagram each of them and determine the following:

- (a) Resistance of its segments.
- (b) Highest possible resistance.
- (c) Lowest possible resistance.
- (d) Carrying capacity (determined for metal, as point where paper is charred; for lamps by their proper voltage).
- (e) Largest power that can be absorbed.
- (f) Combinations of switches to proceed stepwise from highest to lowest resistance.
- (g) Effect of varying current on value of resistance.

N. L. M., Vol. I, 203.

3

WINDINGS AND CONSTANTS OF DYNAMOS.

- (a) In general, the resistance of what three windings of a dynamo are to be measured?
- (b) Which may be absent, and in what sorts of machines?
- (c) Which of these windings are generally made up of two or more equal parts joined in series? Which is made up of two or more equal parts in parallel?
- (d) What two methods of resistance measurement are most adaptable to this, and in general to dynamo work?
- (e) Diagram and explain how, by each of these methods to obtain the resistance of each of the parts which are in series without disconnecting them.
- (f) Can the individual resistance of each of the parallel parts be obtained without disconnecting them, and why?
- (g) What inconstant element makes the exact determination of the armature resistance difficult? Suggest a method for reducing this error. (Always follow this method, taking at least five readings.)

(h) Suggest a method for measuring the contact resistance of the brushes. What precaution to be taken in regard to contacts?

(i) How may the length of the wire on the field magnet be determined? How the approximate number of turns?

(j) Under what circumstances will the resistances measured not be the normal running resistances of the machine?

(k) In such cases how obtain from them the true running resistances?

(n) When impossible to apply micrometer or wire guage how may the size of wires be obtained?

Machines often run from 75° to 100° Fahrenheit above the temperature of the atmosphere. One hundred and eighty degrees is a fair value. Determine running resistance of a series and of a shunt machine; number of turns and size and length of wire on fields and armature; brush contact resistance, noting also kind of brush used, circular mils per ampere in field and in armature.

T. D. E. M., Ch. III; S. & B., 328 to 345; ; H. & K., Ch. II; N. L. M., Vol. II., 8.

4

CONNECTIONS OF DYNAMOS.

(a) Study the machines assigned, to determine whether alternating or direct; series, shunt or compound. Make diagrams of connections of each machine and its regulator. Give data as to voltage, current and output, also types of armature and field magnets.

T. D. E. M., Ch. III and VIII; S. & B., 328 to 345; H. & K., Ch. II.; N. L. M., Vol. II, 8.

5

SERIES AND PARALLEL RESISTANCES.

(a) Give complete directions for calculation of resistances in series and parallel. Make several entirely differ-

ent combinations of the segments of the assigned resistances, measure the resistance of each segment separately, calculate the resistance to be expected in each combination and verify the result by experiment.

S. & B., 22 to 30.

6

STUDY OF INSTRUMENTS.

(a) Name three essentially different types of magnetic measuring instruments and give examples.

(b) Which of the above types cannot be used for measuring alternating currents and why?

(c) Explain the principles employed in the construction of alternating current instruments.

(d) Describe in detail and with diagrams the construction and operation of the instruments assigned.

(e) What three reasons why in stationary magnet types the air-gap should be made as short as possible?

(f) Why is uniformity of field desirable?

(g) What points are gained by having two springs instead of one, for bringing the needle to zero?

(h) Give a structural detail by which error due to parallax is avoided.

(i) Explain, with diagram, the essential differences in the circuits of voltmeters and ammeters, giving parts peculiar to each.

(j) Give method for using a voltmeter for pressures above its range. Same for an ammeter.

(k) What difficulty that does not exist in the above method for voltmeters is found in the case of ammeters, and why?

(l) Explain measurement of current by means of milli-voltmeter and shunt.

(m) Discuss the effect of temperature on voltmeters and on ammeters.

(n) How could the heating of a wire be used to measure current? (Note.—This forms an important though not very accurate class of instruments.)

(o) Describe a method for using electrostatic attraction for an instrument.

(p) Give advantages and disadvantages of this type of instruments.

(q) Give method of making these instruments for low voltages, and for damping the needle.

(r) What type of instrument makes use of electromagnetic repulsion of parallel coils? Describe.

S. & B., parts of Chs. IV & VI; El. W., Vol. XIX, 217, 233, 277; catalogues.

7

FUSE WIRE TEST.

(a) How should the fusing current for fuse wire vary with: (1). Length between terminals? (2). Time of flow of current? (3). Size of terminals?

Take two sizes of wire and leaving current on for ten seconds find fusing current for 1-4", 1", 2" and 3". Try three pieces of each length and take mean of results.

With two sizes of wire try several currents in the vicinity of the fusing current, and note time required to fuse in each case; get a mean of three results for each current.

Find current to fuse two different sizes of wire in ten seconds on different sized terminals.

Short-circuit fuse in each case until the current is adjusted. Plot the results.

Trans. A. I. E. E. 93, Vol. X, 251. N. L. M., Vol. II, 74.

8

LOCATION AND DETERMINATION OF FAULTS. BY RESISTANCE METHODS.

(a) Name the different kinds of faults that may occur in the winding of a dynamo.

- (b) What is meant by a "ground"?
- (c) If there is no ground, how closely can an open circuit in the field winding be located by resistance measurement?
- (d) Same if there is a complete ground at the open circuit?
- (e) Give a method, based on the principle of Wheatstone's bridge for the location of a ground.
- (f) Give a method for determination by resistance method of the proportion of a coil that is short-circuited.
- (g) In the case of a formed coil, give a method for determining in what part of the coil a short circuit is located.
- (h) If the whole, or a large part of a coil were short-circuited, suggest a method for determining that fact with current, but without the use of instruments.
- (i) Given a voltmeter of known high resistance, describe a method, by using it also as a current meter for determining the resistance of a partial ground.
- (j) How determine the highest resistance that can be measured with a given instrument and a given voltage?
- (k) Give directions for locating, by resistance measurement, an open circuit in a closed coil armature.
- (l) Same for a ground.
- (m) Same for a short-circuited coil.
- (n) Same for abnormal resistance between holder and brush and between brush and commutator.

9

PRELIMINARY TO THE RUNNING OF
MACHINES.

Give in detail the effects on the action of the machine of the following, together with the reasons therefor:

- (a) Not having the brushes set at the correct angle.
- (b) Not having the brushes opposite.
- (c) Letting the brushes spark.

(d) Letting the commutator become covered with film of oil and dirt.

(e) Letting the bearings get dry.

(f) Suddenly breaking the field circuit.

(g) Putting too much current through the armature.

(h) Putting resistance in the main circuit of a motor.

(i) In the armature circuit.

(j) In the field circuit.

(k) Effect on speed,—of shifting the brushes.

(l) Increasing the number of ampere turns on the field.

(m) Effect of reversing the direction of the current through the whole machine.

(n) Through the armature.

(o) Starting motor without starting resistance box.

(p) Putting current into the armature with field circuit open.

10

SPEED POTENTIAL CURVE.

(a) Given the E. M. F. of a generator $= \frac{n C \phi}{10^8}$

how should it vary with the speed, i. e., what should the curve be if the flux is constant.

(b) What must be done to keep the flux constant?

(c) Will it do to self excite the machine during the test, and why?

(d) Suppose the field current to be increased or decreased, and then brought directly to its former value, what will be the effect on the curve, and why?

(e) How remedy the above effect?

Obtain this curve for the machine assigned.

To get variable speed, use resistance in series with motor armature.

11

MAGNETIZATION AND HYSTERESIS.

- (a) What is a magnetization curve?
- (b) What is the difference between a magnetization curve and a hysteresis curve?
- (c) Sketch magnetization curves for a dynamo and for the iron part of its magnetic circuit, and explain the difference.
- (d) What does the general inclination of the curve to the X axis indicate?
- (e) What the curvature?
- (f) How, as to scale, must curves of different machines be plotted, to be comparable?
- (g) What does the hysteresis curve show? Explain with sketch.
- (h) Suppose too great an increase is made in the current, and that then it is reduced directly to the required value, what effect is produced on the curve?
- (i) How reach the required value without this effect?
- (j) Why should the speed be kept constant?
- (k) If the speed is not kept as above, how can the readings be corrected for it?
- (l) Can the machine be self-exciting during the test, and why?
- (m) Give the process for obtaining a complete hysteresis curve, and discuss it as indicating the characteristic qualities of the machine.

Note — Regulate motor speed with resistance in its field.

T. D. E. M., 122 to 142; Jackson, Vol. I, 195 to 200; N. L. M., Vol. II, 15.

12

SERIES CHARACTERISTIC.

- (a) Define series characteristic.
- (b) What two different forms of the series characteristic?
- (c) Which is observed?

- (d) How is the other obtained?
- (e) What data of the machine must be known?
- (f) Draw an example of a series characteristic and explain the effects of speed, internal resistance, air gap and quality of iron.
- (g) What element should be kept constant and how can it be corrected for if varied?

Carry test to about 25% overload. Take points closer together where the curvature is greater. Take minute speed readings and mean electrical readings for that period.

N. L. M., Vol. II, 14; T. D. E. M., Ch. X; Jackson, Vol. I, 200 to 208; S. & B., 345 to 353; H. & K., 209 to 211.

13

SHUNT CHARACTERISTIC.

- (a) What two forms of shunt characteristic? Sketch.
- (b) Which is observed?
- (c) What are "resistance lines," and how drawn for armature and fields? Sketch.
- (d) Describe process for obtaining the calculated characteristic.
- (e) What constants of the dynamo must be known for the above calculation?
- (f) What is shown by the slope of the upper part of the curve, in the external characteristic? In the total characteristic? (See Jackson.)
- (g) In the external characteristic, explain why the upper part drops more rapidly as it proceeds further.
- (h) What is the electrical condition of things in the machine when the curve begins to return toward the Y axis?
- (i) What causes the shape of the lowest part of the curve?
- (j) Is it possible to correct for variation in speed and why?
- (k) What effect is produced by putting additional resistance in shunt field circuit and why?

(l) What will be the nature and signification of a curve of field current plotted with armature current, the terminal E. M. F. being left constant. (This curve is sometimes called the armature characteristic).

(m) What will be the effect if a shunt machine is suddenly short-circuited? Is gradually short-circuited?

Obtain total characteristic and armature characteristic.

N. L. M., Vol. II, 17 to 25; Jackson, Vol. I, 200-208; T. D. E. M., Ch. X; S. & B., 353 to 356.

14

COMPOUND CHARACTERISTIC AND REGULATION.

(a) Sketch connections of a compound machine.

(b) Explain the difference between long and short shunts with diagrams.

(c) What would be an ideal compound characteristic?

(d) Explain the action of the shunt and series coils in producing the compound characteristic.

(e) How will the actual compound characteristic differ from the ideal and why?

(f) What is indicated by a falling characteristic? What by a rising characteristic?

(g) What must be done to remedy the former? What two remedies for the latter?

(h) Under what circumstance would a rising characteristic be required?

Take series characteristic and compound characteristic; also regulate compound winding for constant potential, and for 2% over-compounding.

N. L. M., Vol. II, 25; H. & K., 208; S. & B., 357-362

15

POTENTIAL AROUND THE COMMUTATOR.

(a) How does the potential vary between consecutive segments around the commutator?

(b) What is the cause of this variation?

(c) What would be the form of the curve if the machine had but one narrow coil and why? What if there were no iron in the armature?

(d) Discuss the difference between the curve for no load, and that for full load, with causes.

(e) Describe two methods of obtaining curves of potential around the commutator.

(f) Which is the more accurate and why?

(g) How would reversal of the field under a pole-tip be indicated in the curve?

Take curves with both one and two brushes, separately excite the field, and take no load and full load curves with both strong and weak fields, using two brush method.

N. L. M., Vol. II, 63; T. D. E. M., 63-65; Jackson, Vol. I, 208; Am. Elec., March, 1898.

16.

PARALLEL RUNNING OF COMPOUND MACHINES.

(a) Explain why compound machines will not run properly in parallel if only the terminals are connected together.

(b) Describe with diagram an equalizer and its action.

(c) What effect on this action would resistance in the equalizer circuit have?

(d) Discuss effect of form of characteristic on parallel running, and method of making characteristics similar.

(e) What effect on the division of the load will the resistance of the series fields have?

(f) Describe and explain the operation of throwing compound machines in parallel.

Connect up two compound machines with equalizer; and, if possible, adjust to take equal or proportional load from no load to full load. Vary the resistance of one series field and repeat.

T. D. E. M., 766; Jackson, Vol. I, 230-243; P. & S., 331-340; C. & W., 49 to 57.

17.

MAGNETIC LEAKAGE.

- (a) Describe fully the various useful and waste magnetic paths in a dynamo.
- (b) Explain "coefficient of leakage".
- (c) Explain briefly methods of calculation of the coefficient of leakage.
- (d) Describe methods of determination of the above, and also of the leakage in various parts.
- (e) What precautions are necessary in the disposition of the wires in the test coil circuits?

By the above methods obtain both total coefficient and also the leakage in various parts of stray field.

N. L. M., Vol. II, 67; T. D. E. M., 153.

18.

SHUNT MOTORS.

18A. MOTOR TORQUE AND REGULATION.

- (a) Give and discuss the equation for the relation of torque and current.
- (b) Describe the method of obtaining torque.
- (c) Give method for eliminating the error due to mechanical friction.
- (d) Using equation for armature current, discuss the regulation of motor speed, by varying (1) armature resistance, (2) field resistance.
- (e) Discuss effect of changing number of field turns, the voltage remaining constant.
- (f) Give the effect on the regulation of running the motor at different points on its magnetization curve.

18B. EFFICIENCY AND LOSSES BY THE ELECTRICAL METHOD.

- (a) Give three expressions for the commercial efficiency of a dynamo in terms of input and output and losses.

(b) Give a tabular classification of all sources of loss in a dynamo machine indicating which are constant, which dependent upon the load and which upon the speed.

(c) What curves must be taken and what corrections made?

(d) Which losses are proportional to the speed and which to the square of the speed?

18C. EFFICIENCY BY BRAKE.

(a) Describe the Prony Brake, and discuss the theory of its use, giving the proper length of the arm for convenient reduction of the results.

(b) What error results if the brake arm is not horizontal?

Keeping the voltage on the motor constant and normal, obtain curves of speed with armature current under the following conditions,—

(a) With a constant known field current and by varying the load on the brake,—

1. With no resistance in the armature or field, noting in this case also the readings,

2. With constant known resistance in the armature.

3. With constant known resistance in the field,

(b) By varying the resistance in the armature circuit,—

4. With no load, noting also voltage on the armature,

5. With a constant load.

(c) By varying the resistance in the field,—

6. With no load.

7. With a constant known load.

Plot these seven curves on a single sheet.

From the data secured above, calculate and plot curves as follows: iron and friction loss with speed; also, with watts input, the following; speed, iron and friction loss, field loss, armature copper loss, total loss, electrical output, brake output, efficiency by the electrical method and by the brake method.

19.

SERIES MOTORS AND CONTROLLERS.

If 18 has not been taken first, answer questions a, b, and c of 18 A.

(a) Using the equation for armature current, discuss the effect of variation of resistance and of field strength upon the speed.

(b) Compare and discuss starting torque and speed in series and shunt motors.

(c) Describe and explain fully the controller and its action in starting and in regulating the speed of series motors.

Connect up the controller, start and operate with it under various loads, to represent working conditions.

Get the curve of speed with resistance, with no load and with load; also of speed with output, and of starting torque with current.

T. D. E. M., 506; P. & S., 36-55, 481 to 487; S. & B., 469, 470, 478, 490; H. & K., Chs. XXV & XXVI. Bell, 80-88.

20.

LOSSES AND EFFICIENCY OF COMBINED
MOTOR AND GENERATOR.

(a) Describe methods of the operation of two machines at full load by supplying the losses (1) mechanically, (2) electrically; this for both shunt and series machines.

(b) Discuss determination of combined losses and of the efficiencies if equal, of the individual machines.

Operate the machines assigned and obtain losses and efficiency.

Jackson, Vol. I, 254 to 257; T. D. E. M., 758 to 760; N. L. M., Vol. II, 34; P. & S., 356 to 359, 433 to 438.

21.

ARC GENERATOR AND REGULATOR.

(a) Give the general methods in use for constant current regulation.

(b) Describe and explain the machines studied, together with the auxiliary regulating apparatus.

Adjust the regulator and obtain regulation curve.

S. & B., Ch. XI; Jackson, Vol. I, 225 to 229; T. D. E. M., Ch. XVIII; C. & W., 163 to 202.

22.

STUDY OF ARC LAMPS.

(a) Give the functions to be performed by the mechanism of arc lamps of different types

(b) Give a complete classification of arc lamps.

(c) Discuss differences between open and enclosed lamps.

(d) Also between direct and alternating current lamps.

(e) Describe with diagrams the mechanism of the lamps studied.

(f) Discuss electrical efficiency of arc lamps and methods of obtaining the same.

(g) Discuss the regulation of arc lamps, conditions affecting the same, and method for its determination.

Determine the current used, and the volts and watts, consumed by the mechanism; also the electrical efficiency, and regulation curves with the lamp in both good and bad adjustment.

N. L. M., Vol. II, 46; S. & B., 615 to 638.

23.

PHOTOMETRY.

(a) Give and explain the laws of light as applied in photometry, and also the unit used.

(b) Describe and explain the photometers and auxiliary apparatus used.

(c) Discuss fully the measurements assigned and the methods of carrying them out.

(d) What special difficulties in arc photometry and what precautions are necessary?

- (e) Discuss the efficiency of incandescent arc lamps.
- (f) Discuss the life of incandescent lamps.
- (g) Discuss fully the results obtained.

S. & B., 590 to 615; N. L. M., Vol. II, 212 to 223, 318 to 329, 342 to 346.

24.

ILLUMINATION.

- (a) Give and explain the laws and units involved in a study of illumination.
- (b) Explain conditions, other than strength and position of the source of light, that affect illumination.
- (c) Describe and explain the apparatus used.
- (d) Discuss fully the measurements assigned and the results obtained.

S. & B., 704, 705.

25.

ACCUMULATORS.

- (a) Discuss the chemical composition of a charged cell, and the changes resulting from discharge.
- (b) What are the two principal classes of lead cells?
- (c) Discuss the specific gravity of the electrolyte, and its effects on the E. M. F. of the cell.
- (d) Draw curves of charge and of discharge with time, and discuss.
- (e) Give the general relation between discharge rate and capacity, and between discharge rate and efficiency.
- (f) Give the effects of excessive current, and of over-charge.
- (g) To what E. M. F. per cell should the discharge be carried, and what is the advantage of not discharging too far?
- (h) What precautions are to be taken when mixing sulphuric acid with water?
- (i) To what E. M. F. should the charge be carried and what is the effect of carrying it too far?
- (j) Give directions for determining the efficiency of the cell, noting particularly the precautions necessary to insure

that the cell shall be in the same condition at the end of the test as at the beginning.

(k) Give directions for measuring the resistance of the cell.

Obtain curves of E. M. F. and time at a constant rate of charge and at two different constant rates of discharge. Determine the resistance of the cell, and its efficiency. Obtain special curves of E. M. F. and time for short intervals after closing and opening the circuit, both for charge and discharge.

S. & B., Ch. XIV; Trans. A. I. E. E., Vol XI, 302; XII, 585.

26.

STUDY OF LIGHT AND POWER PLANT.

Describe in detail with sketches and diagrams such of the following features as are present in the plant studied.

- (a) The coal carrying machinery;
- (b) The stokers;
- (c) The boilers;
- (d) The ash handling machinery;
- (e) Feed water supply;
- (f) Engines and generators;
- (g) Condensing plant;
- (h) Switch-board, giving directions for making all possible combinations of machines and circuits, and functions of all apparatus;
- (i) Power distribution;
- (j) Light distribution;
- (k) Heat distribution;
- (l) Give all steps to be followed in starting up each of the engines and generators;
- (m) In changing load from one machine to another;
- (n) In shutting down;
- (o) In throwing machines in parallel.

In above descriptions give full data, such as capacity, pressure, etc.

CHAPTER III.

QUESTIONS ON ALTERNATING CURRENT LABORATORY EXPERIMENTS.

27.

SIEMENS ELECTRODYNAMOMETER.

- (a) Describe and sketch the instrument.
- (b) Explain its theory, action and use.
- (c) Explain the effect of reversing one of the coils.
- (d) Does the angle of lag of the current in the circuit have an effect upon the correctness of the dynamometer reading?
- (e) Give the probable effect of the mercury in contact cups not being clean.
- (f) What precaution should be taken to avoid the effect of the earth's field, when calibrating with direct current? Why is this effect not present when using with alternating current?
- (g) Why are very low readings not liable to be accurate?
- (h) To reduce sensitiveness one-half what change should be made in the design?
- (i) How may the instrument be used to determine difference of phase between two currents?

N. L. M., Vol. II, 59; S. & B., 102 to 107; F. & W., 29 to 31; Jackson, Vol. II, 128.

28.

WATTMETERS.

- (a) Explain the theory, action and use of the dynamometer wattmeter.
- (b) Explain the error resulting from appreciable inductance in the shunt circuit.

(c) What is the correcting factor, and why is it not practicable to use it?

(d) Assuming a maximum lag in the line how may the maximum allowable inductance in the shunt circuit be calculated?

(e) What is the error with the shunt coil connected outside of the series coil?

(f) What with it connected between the series coil and the load?

B. T., 369 to 374; S. & B., 542 to 544; Jackson, Vol. II, 131 to 135; F. & W., 36 to 38.

29

STUDY OF INDUCTIVE CIRCUITS.

(A) IMPEDANCE DIAGRAM.

(a) Having given the frequency of an alternating current and the resistance of the circuit, explain how to obtain the coefficient of self-induction.

(b) Show how, with these data, to construct the triangle of impressed, active and inductive E. M. Fs. (virtual.)

(c) How change this to the triangle of maximum E. M. Fs?

(d) How change to the impedance triangle?

(e) The ratio of what quantities determines the shape of this triangle?

(f) What is this ratio called?

(g) Given three voltmeters and a known non-inductive resistance, how can the above triangles be determined?

(h) Explain how to use but one or two voltmeters for this.

(i) What would be the effect of using a voltmeter which took an appreciable amount of current, across the outside of the circuits?

(j) Also across the non-inductive circuit, and how eliminate the effect if the voltmeter is non-inductive?

(k) What effect if used across the inductive circuit?

(l) In a circuit without iron, what effect on the coefficient of self-induction would changing the current have?

(m) Having constructed the triangle for the coil without iron, what would be the effect on it of inserting an iron core?

Construct the virtual E. M. F. and impedance triangles by two methods, both with and without iron.

(B) VARIATION OF RESISTANCE IN AN INDUCTIVE CIRCUIT.

(a) With a constant impressed E. M. F. and a constant inductance, what will be the locus of the right-angle vertex of the E. M. F. triangle?

(b) What will be the locus of the current?

(c) What will be the value of the current when the resistance is zero?

Construct five triangles under these conditions and draw the loci mentioned above.

(C) VARIATION OF INDUCTANCE, THE RESISTANCE BEING CONSTANT.

(a) Show what the locus of the current will be.

(b) Give three different ways by which, without using iron, the inductance of the circuit may be varied.

Get the data for, and construct five triangles as above, also construct the current locus.

(D) BOTH INDUCTANCE AND RESISTANCE VARIED.

(a) If both the inductance and the resistance vary proportionately what will be the effect on the angle of lag?

(b) How will the current vary?

(E) VARIATION OF THE FREQUENCY.

(a) Show what the locus of current will be when the frequency varies.

(b) What will be the values of the current when the frequency is zero and when it is very large?

Obtain triangles for five values of frequency, and construct the above locus.

(F) INDUCTIVE CIRCUITS WITH IRON.

- (a) Why not use a solid iron core?
- (b) Explain the effect on the self-inductance of using different currents.
- (c) What will be the general nature of the curve of self-inductance with current?
- (d) How could the magnetic density of the iron be varied without changing the alternating current?

N. L. M., Vol. II, 110.

With five values of the alternating current construct the curve mentioned. Also try the effect of using a solid core.

F. & W., Chs. I & V; N. L. M., Vol. II, 109 to 123; B. T., 63 to 70.

30.

INDUCTIVE CIRCUITS IN SERIES AND PARALLEL.

- (a) Show how to construct the E. M. F. diagram for several inductive circuits in series.
- (b) Also in parallel.

Obtain the E. M. F. triangles for the different circuits given, and from them construct the diagrams for these circuits both in series and in parallel. Check these diagrams by measurements on the circuits combined.

B. T., 82 to 84; F. & W., Chap. VII.

31.

CIRCUITS CONTAINING CAPACITY.

- (a) Upon what three things does the capacity of a condenser depend?
- (b) What two sources of loss in a condenser?
- (c) How do these losses show themselves in the action of a condenser?

(B) IMPEDANCE DIAGRAM.

(a) Explain the action of a condenser in producing a leading current in a circuit.

(b) With an alternating current of given frequency, how obtain the capacity of a condenser?

(c) Discuss the effect of wave form on the result so obtained.

(d) Show how to construct the E. M. F. and impedance diagrams for a circuit containing resistance, inductance and capacity.

For the circuits given determine the E. M. F. and impedance diagrams.

(C) VARIATION OF CAPACITY AND RESISTANCE.

(a) Discuss and study these points as in the case of circuits with varying resistance and inductance.

B. T., 70 to 77; F. & W., Chs. I & V; N. L. M., Vol. I, 130 to 133, 227 to 231, Vol. II, 170 to 178.

32

CIRCUITS WITH CAPACITY IN SERIES AND IN PARALLEL.

(a) Construct a diagram for the following six circuits in series: (1) with R and L, (2) with R only, (3) with C only, (4) with R and C, (5) with R, L and C, (6) with L only.

(b) For the same circuits in parallel.

(c) What must be the value of the capacity to neutralize the inductance in a series circuit?

(d) Show how to determine graphically the value of the capacity in parallel necessary to bring a given lagging current into phase with its E. M. F.

With the circuits and condensers given, construct and check by measurement series and parallel circuit diagrams; also calculate inductance and capacity to neutralize each other, and check by measurement.

N. L. M., Vol. I, 227 to 231, Vol. II, 178,

33.

CURVE OF MAGNETIC DISTRIBUTION IN GENERATOR.

(a) Describe a method for getting above curve for a generator when not running, using a ballistic galvanometer. Why ballistic?

(b) In this case, just what do the ordinates of the curve represent?

(c) Explain how to obtain the E. M. F. curve from this curve.

(d) Would this be the same as the curve of E. M. F. obtained by the instantaneous contact method at full load, and why?

Obtain the curve for one complete cycle and construct therefrom the E. M. F. curve.

N. L. M., Vol. II, 107 to 109; Jackson, Vol. II, 266 to 271, 278 to 284, 287 to 291.

34.

CURVE OF EFFECTIVENESS OF ARMATURE TURNS IN PRODUCING REACTION ON THE FIELD.

(a) What is the nature of the reaction produced by a coil when its center is under the middle of the pole-piece?

(b) When the center is half way between the pole-pieces?

(c) Describe a method for obtaining a curve whose ordinates shall represent for each position under a pair of poles, the effectiveness of the armature coils in producing forward and back reactions.

(d) Show how, with this and the current curve to construct a curve proportional to the forward and back ampere-turns.

(e) How will this curve show whether the armature reactions will raise or lower the E. M. F. of the machine.

Construct this effectiveness curve, and then with the current curve of the machine, or assuming a sine curve

of current in phase with the E. M. F. construct the reaction curve; do the same for a current curve lagging 30° .

35.

TRANSFORMERS, VOLTAGE RATIO AND REGULATION.

- (a) What is the relation of the primary and the secondary E. M. Fs. in a transformer?
- (b) At what load does the above relation hold?
- (c) What approximate relation between the primary and secondary currents?
- (d) What prevents this relation from being exact?
- (e) With the same current densities in the primary and secondary, what is the relation of their resistances?
- (f) What are the sources of bad regulation in a transformer?
- (g) Give the formula for the most important of these causes of drop in voltage.
- (h) Give the steps to be taken to determine the regulation, having but a single transformer to test?
- (i) How proceed if two similar transformers are available?
- (j) Why is this method more accurate than the use of but one transformer?
- (k) What is the effect on the drop of varying the number of turns?
- (l) What generally limits the drop that can be allowed in a transformer?
- (m) What is the effect of an inductive load on regulation? Explain by use of diagram.
- (n) Define magnetic leakage.
- (o) How does magnetic leakage act in producing drop? Explain by use of diagram.
- (p) How is it best to arrange the windings of a transformer in order to reduce the leakage, and how effective is this method?

(q) A transformer suited to what special use can be made by constructing so as to exaggerate the leakage effect?

By varying the number of turns in the coils, prove the statement made in answers to (a) and (c). Measure resistances and note the agreement with (e). Calculate the copper drop for full load, measure the drop with a single transformer, and if two are available also by method of (i). Note the part of the drop due to leakage.

Place inductances in the load and determine the curve of power-factor and drop with constant secondary current. By taking different combinations of coils in a one-to-one transformer, note effect of change in magnetic leakage on the drop. With transformer arranged to give large magnetic leakage determine the current and E. M. F. characteristic for (q).

F. & W., Ch. X; B. T., Ch. VII; Jackson, Vol. 426 to 450; T. D. E. M., 694 to 700.

36.

TRANSFORMERS, LOSSES AND EFFICIENCIES.

- (a) What are the sources of loss in a transformer?
- (b) Which are independent of the load?
- (c) How determine the iron losses?
- (d) Give methods of obtaining the copper losses.
- (e) What is the effect on the copper losses of increasing the number of turns?
- (f) What on the iron losses?
- (g) In the ordinary transformer what would usually be the effect on the "all day efficiency" of increasing the number of turns, and why is this not done?
- (h) Why is it better to measure the losses than the output and input in determining efficiencies?
- (i) What are the effects on the different losses, and on the losses as a whole, of increasing the periodicity?
- (j) The same for varying voltage?

Measure the losses in the given transformer, and calculate the efficiencies for five loads. Plot the curve,

Determine the iron losses for varying number of turns, for varying E. M. F. and for varying frequency, and plot curves.

F. & W., 137 to 143; B. T. Ch. XVIII; Jackson, Vol. II, Ch. XI; N. L. M., Vol. II, 136 to 140.

37.

STUDY OF POLYPHASE CURRENTS.

(a) In a 2-phase 3-wire system, what relation does the current in the common return bear to that in the other wires?

(b) What is the relation of the E. M. Fs. in the above system?

(c) In a ring winding supplied by a 2-phase 4-wire system at points 90° apart what are the relations of the E. M. Fs. and currents in the quadrants and lines; demonstrate by diagrams?

(d) In this case why not use a system with a common return? How can such be used with the addition of a one-to-one transformer?

(e) Discuss E. M. Fs. and currents in a three-phase system, both star and mesh connected.

Demonstrate the answers to the above experimentally.

F. & W., Ch. VIII; Jackson, Vol. II, 546 to 555.

38.

POLYPHASE POWER MEASUREMENT.

(a) Give diagram showing connections of a wattmeter for measurement of power in 2-phase 4-wire, 2-phase 3-wire, and 3-phase systems.

(b) In a 2-phase 3-wire system, explain why, if the phases are exactly 90° apart, one wattmeter in the common return can be used, also the effect on these measurements if the phases are not exactly in quadrature.

(c) Draw diagram for using one wattmeter and throw-over switches for a 2-phase 3-wire system.

(d) Explain how to use wattmeter to show if phases are exactly in quadrature.

Connect up and measure the power in the circuits given.

F. & W., 93; Jackson, Vol. II, 557 to 570.

39.

POLYPHASE MOTORS.

(a) How as compared with D. C. motors is the ratio of starting to full load running torque?

(b) Explain the effect on the starting torque and on the regulation, of varying the resistance of the secondary.

(c) Effect of varying the E. M. F. on the starting torque and on the speed.

(d) Effect of varying the frequency on the speed of the motor. What determines the no-load speed of the motor?

(e) Explain the object of the starting ring on motors with revolving primary.

(f) Object of starting transformer with revolving secondary.

(g) Effect on iron losses of using the revolving primary.

Get the starting torque of the motor and its relation to running torque at full load. Compare this with the same for direct current motors. Vary the resistance in the secondary and note effect on the starting torque and on the regulation. Vary the E. M. F. and note the difference in the starting torque and in the load necessary to stall the motor; plot curves. If practicable, note difference of temperature after short no-load run, of the iron in the primary and in the secondary.

F. & W., Ch. XIV; Jackson, Vol. II, 591 to 633.

40.

PARALLEL ALTERNATORS AND SYNCHRO-
NOUS MOTORS.

(a) What are the conditions which permit of electrically connecting two alternators, and how are those shown by the use of synchronizing lamps?

(b) When an alternator is running as a motor, what is the effect of changing its excitation on the phase relation of the E. M. F. and current? Explain.

(c) Explain the effect of changing the motor-load on the above phase relation?

(d) What is the effect of over-loading a synchronous motor?

(e) Explain how the counter E. M. F. is decreased with increase of load?

(f) Give three methods for telling whether a synchronous alternator is running as a motor or a generator.

Run the machine as a synchronous motor and vary the field strength; with constant load determine curves of load current and phase angle with varying field current. Put an inductive circuit in parallel with the motor, and note the capacity effect of the motor. Running the machine as a motor, load it till it breaks from synchronism. Plot curve between exciting current and load necessary to pull out of step. Run two machines in parallel, and as the excitation of one is decreased note the change from generator to motor.

F. & W., Ch. XII. N. L. M., Vol. II, 144; Jackson, Vol. II, 571 to 590.

41.

INSTANTANEOUS CONTACT METHOD AND
GENERATOR CURVES.

(a) Name two classes of contact makers (as to method of making the contact).

(b) Describe three general methods of voltage determination in instantaneous work.

(c) What is the usual method for obtaining the curves for current.

(d) Give and explain the uses of condensers in instantaneous contact work.

(e) Draw diagram of circuits necessary to obtain E. M. F. and current curves from a generator. Show what part should be grounded and give effects on the readings of additional grounds at other parts of the circuits.

(f) What is the effect of inductive and capacity loads on the regulation of a generator. Explain.

Obtain E. M. F. and current curves for a generator by one or more methods, for no load, one-half load and full load, also for inductive load and capacity load. Note effect of latter on regulation.

F. & W., Ch. II; N. L. M., Vol. II, 93 to 104; Jackson, Vol. II, 291 to 304.

42.

INSTANTANEOUS CURRENT AND E. M. F. CURVES ON TRANSFORMERS.

(a) Draw diagram of circuits for determining transformer curves.

(b) Explain effect on curves of variation of load, of inductive load, of capacity load, and of too high density.

(c) Show how, from the curves, to obtain watts supplied to the primary.

Obtain complete curves for no load, one-half load and full load, also for inductive load and capacity load. Also by increase of voltage or decrease of number of turns, determine effect of too high density on the no-load current curve.

B. T., Ch. XVII; Jackson, Vol. II, 450 to 460.

APPENDIX.

LABORATORY METHODS AND APPARATUS.

No attempt will be made to give a complete discussion of these, but a few points that have proved especially successful will be mentioned.

CALIBRATION ROOM.

In order to encourage regular calibration of the instruments used, it is well to have a room fitted up so as to make this operation as convenient as possible; that is, so that it will only be necessary to connect in the instrument to be calibrated, throw switches and adjust resistances. With such arrangements a calibration of all instruments once for every test is easily practicable. A convenient plan is to use a two or three scale standard voltmeter, having a low scale, say $1\frac{1}{2}$ volts, and with standard resistance, all calibrations both of current and voltage are referred to the same instrument.

LABORATORY NOTE BOOKS.

The student should learn to regard his note-book with the same esteem that an engineer does; it should be a repository of the original data and computed results, and not a copy-book to be valued chiefly for its nice appearance. For this purpose a standard note-book is desirable, one that shall be durable, convenient to carry in the pocket; not easily soiled, and of sufficient cost to make the student value it from the start. A form that has proven its usefulness may be described as follows: it has leather covers about $3\frac{3}{4}$ in. $\times$ $6\frac{1}{4}$ in. with pages of good heavy paper; is specially ruled, having besides a blue cross ruling about .16 in. apart red lines for every fifth each way and purple head-lines, making

it convenient for columns of figures, and also for simple curves, sketches, etc. Such a book may be made for 25 cents each.

CONNECTORS.

A liberal supply of connectors is very important and very difficult to keep up. The difficulty has been solved by the laboratory having its own patterns and jigs and making a well designed connector with extra large wire holes and screws that completely fill these when screwed down. These are numbered in sets of four and are kept in a wall-case having a pigeon-hole for each number. The connectors are given out to the students at the beginning of the year on payment of a deposit and are seldom lost.

PART II

PART II.

TABLES
FOR
ELECTRICAL ENGINEERS

COMPILED BY
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COLUMBUS, OHIO

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PREFACE.

Among the following tables have been included only such as are of most frequent use to the electrical engineer. The aim has been to make these accurate to one-half per cent., after granting the assumptions upon which they are based, and which are in each case given. These features are unusual in wire tables. Tables similar to those for copper, have also been added for aluminum and iron. The latter represent average iron, but may be corrected for any other iron the exact specific resistance of which is known. The table for weight and thicknesses of insulations have been compiled as the average of a number of makes and will be useful as approximations. A number of other tables that are not usually found have been added.

PROPERTIES OF BARE COPPER AND ALUMINUM WIRE.

No. B. & S. 4° 3° 2° 0	Diam.	Area	Diam.	Area	Weight in pounds per 1000 feet		Weight in Kilos per kilo- meter	
	Mils	Circular Mils	Milli- meters	Circular milli- meters	Copper sp.gr.-8.93	Alum- inum sp.gr.-2.67	Copper	Alum- inum
4°	460.	211600.	11.68	136.50	643.4	192.4	957.	286.
3°	409.6	167800.	10.40	108.20	510.2	152.6	759.	227.
2°	364.8	133100.	9.266	85.85	404.6	121.0	602.	180.
0	324.9	105500.	8.251	68.08	320.9	95.92	478.	142.8
1	289.3	83690.	7.348	53.99	254.5	76.08	379.	113.2
2	257.6	66370.	6.544	42.82	201.8	60.34	300.	89.8
3	229.4	52630.	5.827	33.96	160.0	47.85	238.	71.2
4	204.3	41740.	5.190	26.93	126.9	37.95	189.	56.5
5	181.9	33100.	4.621	21.35	100.6	30.09	150.	44.8
6	162.0	26250.	4.115	16.94	79.8	23.86	118.8	35.5
7	144.3	20820.	3.665	13.43	63.3	18.93	94.2	28.2
8	128.5	16510.	3.264	10.65	50.2	15.01	74.7	22.34
9	114.4	13090.	2.906	8.446	39.8	11.90	59.2	17.71
10	101.9	10380.	2.588	6.699	31.6	9.44	47.0	14.05
11	90.74	8234.	2.305	5.312	25.04	7.48	37.3	11.14
12	80.81	6530.	2.053	4.213	19.85	5.94	29.55	8.83
13	71.96	5178.	1.828	3.341	15.74	4.71	23.43	7.01
14	64.08	4107.	1.628	2.649	12.49	3.73	18.58	5.56
15	57.07	3257.	1.450	2.101	9.90	2.96	14.74	4.41
16	50.82	2583.	1.291	1.666	7.85	2.348	11.69	3.49
17	45.26	2048.	1.150	1.321	6.23	1.862	9.27	2.77
18	40.30	1624.	1.024	1.048	4.94	1.477	7.35	2.355
19	35.89	1288.	.9116	.8310	3.92	1.171	5.83	1.743
20	31.96	1022.	.8118	.6590	3.11	.929	4.62	1.382
21	28.46	810.1	.7229	.5226	2.46	.736	3.67	1.096
22	25.35	642.5	.6438	.4145	1.95	.584	2.907	.869
23	22.57	509.4	.5733	.3287	1.55	.463	2.305	.689
24	20.10	404.0	.5105	.2607	1.23	.367	1.823	.547
25	17.90	320.4	.4546	.2067	.974	.291	1.450	.433
26	15.94	254.1	.4049	.1639	.773	.231	1.150	.344
27	14.20	201.5	.3605	.1300	.613	.183	.912	.2726
28	12.64	159.8	.3211	.1031	.486	.1453	.723	.2162
29	11.26	126.7	.2859	.08177	.385	.1152	.573	.1714
30	10.025	100.5	.2546	.06484	.306	.0914	.455	.1360
31	8.928	79.71	.2268	.05142	.242	.0725	.360	.1078
32	7.950	63.20	.2019	.04077	.192	.0575	.286	.0855
33	7.080	50.13	.1798	.03234	.1524	.0456	.227	.0678
34	6.304	39.74	.1601	.02564	.1208	.0361	.180	.0538
35	5.614	31.52	.1426	.02034	.0958	.0287	.1426	.0426
36	5.000	25.00	.1270	.01613	.0760	.0227	.1131	.0338
37	4.453	19.83	.1131	.01279	.0603	.0180	.0897	.0268
38	3.965	15.72	.1007	.01014	.0478	.0143	.0711	.0213
39	3.531	12.47	.08969	.008044	.0379	.0113	.0564	.0169
40	3.144	9.888	.07986	.006379	.0301	.0090	.0447	.0134

RESISTANCE OF COPPER WIRE.

B.&S. No.	*OHMS per 1000 feet	Differ- ence per 10° F.	Differ- ence per 10° C.	OHMS per kilo- meter	Differ- ence per 10° F.	Differ- ence per 10° C.	†Fusing current
4°	.04893	.00107	.00193	.1605	.00351	.0631	.....
3°	.06170	.00132	.00243	.2024	.00443	.0797	.....
2°	.07780	.00170	.00306	.2553	.00553	.1005	.....
0	.09811	.00214	.00386	.3219	.00704	.1267	.....
1	.1237	.00270	.00487	.4059	.00837	.160	.....
2	.1560	.00341	.00614	.5118	.0112	.201	.....
3	.1967	.00430	.00774	.6454	.0141	.254	.....
4	.2480	.00542	.00976	.8138	.0178	.320	.....
5	.3128	.00684	.0123	1.026	.0224	.404	.....
6	.3944	.00862	.0155	1.294	.0283	.509	.....
7	.4973	.0109	.0195	1.632	.0357	.642	.....
8	.6271	.0137	.0247	2.058	.0450	.810	.....
9	.7908	.0173	.0311	2.595	.0567	1.021	.....
10	.9972	.0218	.0392	3.272	.0715	1.288	333.
11	1.257	.0275	.0495	4.126	.0902	1.62	230.
12	1.586	.0347	.0624	5.202	.1138	2.05	235.
13	1.999	.0437	.0787	6.545	.1434	2.58	198.
14	2.521	.0551	.0992	8.272	.1809	3.26	166.
15	3.179	.0695	.1251	10.67	.2281	4.10	140.
16	4.009	.0877	.1578	13.15	.288	5.18	117.
17	5.055	.1105	.199	16.59	.363	6.53	98.6
18	6.374	.1394	.251	20.91	.457	8.23	82.9
19	8.038	.1757	.316	26.37	.577	10.38	69.7
20	10.14	.2216	.399	33.25	.727	13.09	53.5
21	12.78	.2794	.503	41.93	.917	16.50	49.2
22	16.12	.3524	.634	52.87	1.156	20.81	41.3
23	20.32	.4443	.800	66.67	1.458	26.24	34.7
24	25.63	.5603	1.009	84.08	1.838	33.09	29.2
25	32.31	.7065	1.272	106.0	2.265	41.72	24.5
26	40.75	.891	1.64	133.7	2.92	52.61	20.6
27	51.38	1.123	2.02	163.6	3.69	66.34	17.3
28	64.79	1.417	2.55	212.6	4.65	83.66	14.56
29	81.70	1.786	3.22	268.0	5.86	105.5	12.24
30	103.0	2.252	4.04	338.0	7.39	133.0	10.28
31	129.9	2.84	5.11	426.2	9.32	167.7	8.64
32	163.8	3.53	6.45	537.4	11.75	211.5	7.26
33	206.6	4.55	8.13	677.7	14.82	266.7	6.10
34	260.5	5.70	10.25	854.6	18.68	336.3	5.13
35	328.4	7.18	12.93	1078.	23.56	418.3	4.31
36	414.2	9.06	16.30	1359.	29.7	534.8	3.62
37	522.2	11.42	20.55	1713.	37.5	674.3	.....
38	658.5	14.40	25.92	2161.	47.2	850.3	.....
39	830.4	18.16	32.68	2718.	59.6	1072.0	.....
40	1047.0	22.9	41.2	3435.	75.1	1352.0	.....

*At 68° F., or 20° C. Resistance of one circ. mil-foot is taken as 9.59 at 0° C.

† $C = ad^{\frac{3}{2}}$; a for copper = 10244.

RESISTANCE OF ALUMINUM WIRE.

No. B.&S.	*OHMS per 1000 feet	Differ- ence per 10° F.	Differ- ence per 10° C.	OHMS per kilo- meter	Differ- ence per 10° F.	Differ- ence per 10° C.	†Fusing current
4°	.08143	.00170	.00306	.2672	.00557	.0100	.....
3°	.1027	.00214	.00384	.3369	.00703	.0127	.....
2°	.1295	.00270	.00486	.4248	.00886	.0160	.....
0	.1633	.00341	.00613	.5356	.0111	.0201	.....
1	.2059	.00430	.00773	.6754	.0141	.0254	.....
2	.2596	.00542	.00975	.8517	.0177	.0320	.....
3	.3274	.00683	.0123	1.074	.0224	.0403	.....
4	.4123	.00861	.0155	1.354	.0282	.0509	.....
5	.5205	.0109	.0196	1.708	.0356	.0642	.....
6	.6564	.0137	.0247	2.153	.0449	.0809	.....
7	.8277	.0173	.0311	2.715	.0567	.102	.....
8	1.044	.0218	.0392	3.424	.0715	.129	.....
9	1.316	.0275	.0494	4.318	.0901	.162	.....
10	1.659	.0346	.0623	5.444	.114	.200	247.
11	2.093	.0437	.0786	6.865	.143	.253	207.
12	2.639	.0551	.0991	8.657	.181	.325	174.
13	3.327	.0694	.125	10.91	.223	.410	146.
14	4.196	.0876	.158	13.76	.287	.517	123.
15	5.291	.110	.199	17.76	.362	.652	103.
16	6.671	.139	.251	21.89	.457	.822	86.9
17	8.412	.176	.316	27.60	.576	1.04	73.0
18	10.61	.221	.398	34.80	.726	1.31	61.4
19	13.38	.279	.502	43.89	.916	1.65	51.6
20	16.87	.352	.634	55.34	1.15	2.08	43.3
21	21.27	.444	.799	69.78	1.46	2.62	36.4
22	26.82	.560	1.01	87.99	1.84	3.31	30.6
23	33.82	.706	1.27	110.9	2.32	4.17	25.7
24	42.64	.890	1.60	139.9	2.92	5.26	21.6
25	57.77	1.12	2.02	176.4	3.68	6.63	18.2
26	67.81	1.42	2.55	222.5	4.64	8.36	15.3
27	85.50	1.73	3.21	280.5	5.85	10.5	12.8
28	107.8	2.25	4.05	353.7	7.38	13.3	10.8
29	136.0	2.84	5.11	446.0	9.31	16.8	9.06
30	171.4	3.58	6.44	562.5	11.7	21.1	7.61
31	216.2	4.51	8.12	709.2	14.8	26.6	6.40
32	272.6	5.69	10.2	894.3	18.7	33.6	5.38
33	343.7	7.17	12.9	1128.0	23.5	42.4	4.52
34	423.6	9.05	16.3	1422.0	29.7	53.4	3.80
35	546.6	10.4	20.1	1793.0	37.4	67.4	3.19
36	689.2	14.4	25.9	2261.0	47.2	85.0	2.63
37	869.1	18.1	32.6	2851.0	59.5	107.0	.....
38	1096.0	22.9	41.2	3595.0	75.0	135.0	.....
39	1382.0	28.8	51.9	4534.0	94.6	170.0	.....
40	1743.0	36.4	65.5	5717.0	119.	215.0	.....

*At 68° F., or 20° C. Resistance of one circ. mil-foot taken = 15.983 at 0° C.

† $C = ad^{\frac{3}{2}}$, a for aluminum = 7585.

PROPERTIES OF IRON WIRE.

Size B.W.G.	Diam. mils	Area circ. mils	Diam. m. m.	Area circ. m. m.	*Pounds per 1000 feet	Kilos. per Kilo- meter.	Nearest B. & S. No.	Diam. nearest B. & S. No.
0	340	115600.	8.636	74.58	304.5	453.2	0	324.9
1	300	90000.	7.620	58.06	237.0	352.7	1	289.3
2	284	80656.	7.214	52.04	212.5	316.2	1	289.3
3	259	67081.	6.579	43.28	176.7	263.0	2	257.6
4	238	56644.	6.045	36.54	149.2	222.1	3	229.4
5	220	48400.	5.588	31.23	127.5	189.8	3	229.4
6	203	41209.	5.156	26.59	108.6	161.6	4	204.3
7	180	32400.	4.572	20.90	85.3	127.0	5	181.9
8	165	27225.	4.191	17.56	71.7	106.7	6	162.0
9	148	21904.	3.759	14.13	57.7	85.9	7	144.3
10	134	17956.	3.404	11.58	47.3	70.4	8	128.5
11	120	14400.	3.048	9.290	37.9	56.5	9	114.4
12	109	11881.	2.769	7.665	31.3	46.6	9	114.4
13	95	9025.	2.413	5.822	23.8	35.4	11	90.74
14	83	6889.	2.108	4.445	18.1	26.9	12	80.81
15	72	5184.	1.829	3.344	13.7	20.3	13	71.96
16	65	4225.	1.651	2.726	11.13	16.56	14	64.08
17	58	3364.	1.473	2.170	8.86	13.19	15	57.07
18	49	2401.	1.245	1.549	6.33	9.41	16	50.82
19	42	1764.	1.067	1.138	4.65	6.92	18	40.30
20	35	1225.	.8890	.7903	3.23	4.80	19	35.89
21	32	1024.	.8128	.6606	2.70	4.015	20	31.96
22	28	784.	.7112	.5058	2.07	3.074	21	28.46
23	25	625.	.6350	.4032	1.65	2.450	22	25.35
24	22	484.	.5588	.3123	1.275	1.897	23	22.57
25	20	400.	.5080	.2581	1.054	1.568	24	20.10
26	18	324.	.4572	.2090	.854	1.270	25	17.90
27	16	256.	.4064	.1652	.674	1.004	26	15.94
28	14	196.	.3556	.1265	.516	.768	27	14.20
29	13	169.	.3302	.1090	.445	.663	28	12.64
30	12	144.	.3048	.0929	.379	.565	28	12.64
31	10	100.	.2540	.06452	.2634	.3920	30	10.025
32	9	81.	.2286	.05226	.2134	.3176	31	8.928
33	8	64.	.2032	.04129	.1686	.2509	32	7.950
34	7	49.	.1778	.03161	.1291	.1921	33	7.080
35	5	25.	.1270	.01613	.0659	.0980	36	5.000
36	4	16.	.1016	.01032	.0422	.0627	38	3.965

*583 pounds per cubic foot; weight per 1,000 feet = .002634xd³.

RESISTANCE OF IRON WIRE.							
No. B.W.G.	*Ohms per 1000 feet	Differ- ence per 10° F.	Differ- ence per 10° C.	Ohms per kilo- meter	Differ- ence per 10° F.	Differ- ence per 10° C.	Feet per ohm at 180° F.
0	.649	.0193	.0348	2.13	.0634	.114	1078.
1	.834	.0248	.0447	2.74	.0814	.147	840.
2	.930	.0277	.0498	3.05	.0908	.164	752.
3	1.12	.0333	.0599	3.67	.109	.197	626.
4	1.32	.0394	.0710	4.35	.129	.233	528.
5	1.55	.0461	.0831	5.09	.151	.273	451.
6	1.82	.0542	.0976	5.97	.178	.320	384.
7	2.32	.0689	.124	7.60	.226	.407	302.
8	2.76	.0820	.148	9.04	.269	.484	254.
9	3.43	.102	.184	11.2	.334	.602	204.
10	4.18	.124	.224	13.7	.408	.735	167.5
11	5.21	.155	.279	17.1	.509	.916	134.3
12	6.32	.183	.338	20.7	.617	1.11	110.8
13	8.31	.247	.445	27.3	.812	1.46	84.2
14	10.9	.324	.584	35.7	1.06	1.91	64.3
15	14.5	.431	.775	47.5	1.41	2.54	48.4
16	17.8	.529	.952	58.3	1.73	3.12	39.4
17	22.3	.664	1.20	73.2	2.18	3.92	31.4
18	31.3	.930	1.67	103.	3.05	5.49	22.4
19	42.5	1.27	2.28	140.	4.15	7.46	16.45
20	61.3	1.82	3.28	201.	5.98	10.8	11.43
21	73.3	2.18	3.93	240.	7.16	12.9	9.55
22	95.7	2.85	5.13	314.	9.35	16.8	7.31
23	120.	3.57	6.43	394.	11.7	21.1	5.83
24	155.	4.61	8.31	509.	15.1	27.3	4.51
25	188.	5.58	10.1	615.	18.3	33.0	3.73
26	232.	6.89	12.4	760.	22.6	40.7	3.02
27	293.	8.72	15.7	962.	28.6	51.5	2.39
28	383.	11.4	20.5	1260.	37.4	67.3	1.83
29	444.	13.2	23.8	1460.	43.3	78.0	1.58
30	521.	15.5	27.9	1710.	50.9	91.6	1.34
31	750.	22.3	40.2	2460.	73.3	132.0	.933
32	926.	27.6	49.6	3040.	90.5	163.0	.756
33	1170.	34.9	62.8	3860.	114.0	206.0	.570
34	1530.	45.6	82.0	5020.	150.0	269.0	.457
35	3000.	89.3	161.0	9850.	293.0	528.0	.233
36	4690.	140.0	251.0	15400.	458.0	824.0	.149

*At 68° F., or 20° C. Resistance of one circ. mil-foot is taken as 67 ohms at 0° C.

MAGNET WIRE.

Single cotton covered.

Double cotton covered.

No. B. & S.	Diam. mils	Lbs. per 1000 feet	Feet per pound	Turns per lin- ear in.	Diam.	Lbs. per 1000 feet	Feet per pound	Turns per lin- ear inch
1	.....	.....	.....	.....	309	259.3	3.86	3.2
2	.....	.....	.....	.....	278	205.8	4.87	3.6
3	.....	.....	.....	.....	249	163.4	6.12	4.0
4	216	129	7.75	4.6	221	130.0	7.70	4.5
5	194	102.5	9.8	5.1	200	102.9	9.70	5.0
6	172	81.3	12.3	5.8	180	82.0	12.2	5.6
7	154	64.4	15.5	6.5	160	65.0	15.4	6.2
8	138	51.2	19.5	7.2	144	51.9	19.3	7.0
9	124	40.6	24.6	8.0	130	41.4	24.1	7.8
10	112	32.3	31.0	8.9	118	33.0	30.3	8.5
11	101	25.7	38.9	9.9	107	26.4	37.9	9.4
12	88	20.3	49.3	11.3	97	21.1	47.4	10.3
13	79	16.1	62.1	12.6	88	16.9	59.2	11.4
14	71	12.8	78.1	14.1	80	13.5	74.1	12.5
15	64	10.2	98.0	15.6	71	10.7	93.5	14.0
16	58	8.1	123.5	17.2	65	8.6	116.3	15.4
17	50	6.4	156.2	20.0	57	6.8	147.1	17.6
18	45	5.1	196.1	22.2	52	5.4	185.2	19.3
19	41	4.1	244.	24.4	48	4.37	229.0	20.8
20	37	3.24	309.	27.0	44	3.54	283.0	22.7
21	33	2.60	385.	30.3	40	2.86	350.	25.0
22	30	2.07	483.	33.3	37	2.33	430.	27.0
23	27	1.67	600.	37.0	34	1.91	524.	29.4
24	25	1.33	750.	40.0	32	1.55	645.	31.2
25	23	1.06	945.	43.5	30	1.26	794.	33.3
26	21	.85	1175.	47.5	28	1.03	970.	35.7
27	19	.68	1470.	52.5	26	.83	1200.	38.5
28	18	.54	1850.	55.5	24	.67	1490.	41.7
29	16	.43	2325.	62.5	23	.55	1820.	43.5
30	15	.34	2940.	66.6	20	.43	2325.	50.0

TABLE OF MATERIALS.

	Tensile strength lbs. per sq. in.	*Specific gravity.	Wt. in lbs. per cu. in.	Resistance at 0° C.		Temperature coefficient.	
				Per circ. mil-foot	Per circ. milli- meter	From 0° to 20° C.	From 0° to 100° C.
Silver, annealed		10.5	.379	9.02	.0191	.00377	.004
Copper, annealed	60000	8.93	.323	9.59	.0203	.004	.0042
Silver, hard				9.78	.0207		
Copper, hard	32000	8.89	.321	9.78	.0207		
Gold, annealed		19.32	.698	12.37	.0262	.00365	.00377
Gold, hard				12.56	.0266		
Aluminum, av. com'l... to 55000 }	24000 } 55000 }	2.6 } -2.8 }	.091 } -.102 }	15.2 } -17.8 }	.0322 } -.0377 }		
Aluminum, pure ann'l'd		2.67	.0964	15.98	.0338	.0039	.0042
Zinc	7000	6.86	.248	33.75	.0714	.00365	.004
Brass (2 cop., 1 zinc)..	45000	8.55	.309	34.42	.0728		
Platinum	53000	20.3	.733	54.4	.115	.00376	.00367
Iron, pure annealed.....		7.7	.278	57.5	.122	.005	.0062
Iron, av. com'l wire.....	56000	7.75 } -7.85 }	.280 } -.283 }	67.0	.142	.006	.006
Nickel		7.8	.282	74.8	.158		
Tin	4600	7.3	.264	79.3	.168		
Lead		11.45	.414	118.0	.250	.00387	.0041
Ger. sil. (18% nickel)..				187.9	.398	.00027	
Ger. sil. (30% nickel)..				292.3	.619	.00027	
Platinoid				201.4	.426	.00021	.00031
Plat. sil. (Pt. 67, Ag. 33)				146.3	.310	.00031	.00024
Antimony		6.7	.242	213.	.451	.00389	
†Mang. (Cu84,Ni4,Mn12)				286.	.605	.00001	.00001
Mercury		13.6	.491	567.5	1.20	.00072	
Bismuth		9.8	.354	787.3	1.67	.00354	

*Water at 39.1° F., or 4° C. Weight of 1000 mil-feet of water at 4° C. = .0003405 pounds.
† Manganin.

SPECIFIC RESISTANCE.

Per mil-foot.

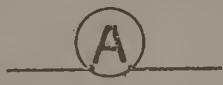
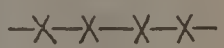
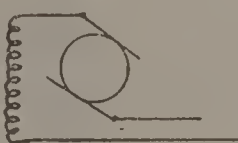
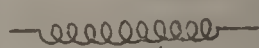
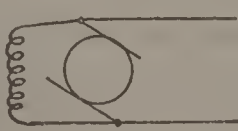
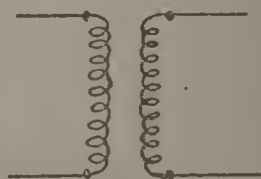
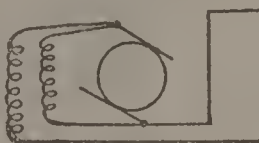
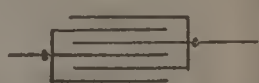
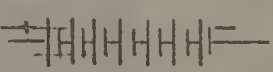
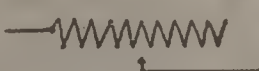
Temp. in Cent.	Temp. in Fahr.	Copper.	Aluminum.	Average iron.
0	32	9.59	16.0	67.
5	41	9.78	16.3	69.0
10	50	9.97	16.6	71.0
15	59	10.14	16.9	73.0
20	68	10.35	17.3	75.0
25	77	10.55	17.6	77.0
30	86	10.75	17.9	79.1
35	95	10.95	18.2	81.1
40	104	11.16	18.5	83.1
45	113	11.36	18.9	85.1
50	122	11.57	19.2	87.1
55	131	11.77	19.5	89.1
60	140	11.98	19.8	91.1
65	149	12.19	20.1	93.1
70	158	12.40	20.5	95.2
75	167	12.61	20.8	97.2
80	176	12.82	21.1	99.2
85	185	13.03	21.4	101.2
90	194	13.23	21.7	103.2
95	203	13.43	22.1	105.2
100	212	13.64	22.4	107.2

ENGLISH-METRIC.

Equivalents.

1 centimeter.	.3937 inch.	1 cir. mil.	.000507 sq. mm.
1 inch.	2.5400 cm.	1 sq. mm.	1973.5 cir mils.
1 millimeter.	39.37 mils.	1 sq. mm.	1.2732 cir. mm.
1 mil. (.001 inch)	.0254 mm.	1 cir. mm.	.7854 sq. mm.
1 meter.	3.2809 feet.	1 cir. mil.	.0006452 cir. mm.
1 foot.	.3048 m.	1 cir. mm.	1550 cir mils.
1 kilometer.	.6214 mile.	1 cubic cm.	.0610 cu. in.
1 mile.	1.6093 kilometer.	1 cubic inch.	16.3867 cu. cms.
1 sq. inch.	6.4516 sq. cms.	1 avoird. pound.	.4536 kilogram
1 sq. cm.	.1550 sq. in.	1 kilogram.	2.2046 lbs.
1 sq. mil.	1.2732 cir. mil.	1 kilogr.—meter.	7.233 ft-lbs.
1 cir mil.	.7854 sq. mil.	1 foot-pound.	.1383 kilogr-m.

CONVENTIONAL DIAGRAMS.

			
DIRECT CURRENT MACHINE	AMMETER	FUSE	GROUND
			
ALTERNATOR	VOLTMETER	NON-INDUCTIVE RESISTANCE	ARC CIRCUIT
			
SERIES MACHINE	WATTMETER	INDUCTIVE RESISTANCE	INCANDESCENT CIRCUIT
			
SHUNT MACHINE	SWITCH	TRANSFORMER	INCANDESCENT LAMP
			
COMPOUND MACHINE	KNIFE SWITCH	CROSSING WIRES	CONDENSER
			
BATTERY	VARIABLE RESISTANCE	JOINED WIRES	PERIODS

PERMEABILITY OF IRON.

B	Magnetising force (H) for Iron and Steel Forgings.		Magnetising force (H) for Steel Castings.		Magnetising force (H) for Armature Stampings.		H for Cast Iron.
1,000	1.0	....	.9	1.9	....	1.7	....
2,000	1.6	....	1.2	2.1	....	2.2	2.4
3,000	1.8	....	1.4	2.4	....	2.6	3.8
4,000	2.0	....	1.7	2.8	....	2.9	6.4
5,000	2.2	....	1.9	3.2	....	3.2	10.8
6,000	2.4	....	2.2	3.6	....	3.6	17.4
7,000	2.8	....	2.4	4.1	....	4.0	26.8
8,000	3.1	....	2.8	4.8	2.3	4.6	39.7
9,000	3.5	....	3.4	5.6	2.9	5.2	58.0
10,000	3.8	4.6	4.0	6.7	3.5	6.1	....
11,000	4.1	5.0	5.1	8.0	4.4	7.2	....
12,000	4.8	5.7	6.6	9.6	5.6	8.8	....
13,000	5.6	7.0	8.8	11.6	8.0	11.2	....
14,000	7.3	8.8	12.7	14.9	12.4	15.0	....
15,000	10.3	13.2	20.0	*20.0	20.6	*22.0	....
16,000	16.4	25.5	27.4	36.0	36.0	38.5	....
17,000	34.5	44.5	45.0	72.0	60.0	80.0	....
18,000	72.0	83.0	78.0	126.0	100.0	....	....
19,000	120.0	....	130.0	....	165.0	....	....

The above values for wrought iron and steel are from curves published in the London Electrician, Vol. 39, page 670, and attributed to Ewing. Those for cast iron are given by Corsepius (1894). In the former minimum and maximum values are given in each case. The curves from which the values are taken cross at the points marked *.

Four Place
Logarithmic and Trigonometric
Tables

ARRANGED BY
F. C. CALDWELL

Columbus, Ohio

L.

FOUR PLACE LOGARITHMS.

											Proportional parts.								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

FOUR PLACE LOGARITHMS.

											Proportional parts.								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9633	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4
100	0000	0004	0009	0013	0017	0022	0026	0030	0035	0039	0	1	1	2	2	3	3	3	4
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

	Number.	Log.		Number.	Log.
II, ... ²² / ₇	3.1416	0.49715	Inches in meter.....	39.3704	1.5952
Naperian base, <i>e</i>	2.7183	0.4343	Cm. in inch.....	2.5400	0.4048
Modulus, <i>M</i>	.4343	1.6378	Cm. in foot.....	30.480	1.4840
<i>g</i> , feet per second...	32.2	1.5079	Feet in meter.....	3.2808	0.5160
<i>g</i> , cm. per second..	980.2	2.9913	Km. in mile.....	1.6093	0.2067
Mech. equivalent....	778	2.8910	Sq. cm. in sq. inch.....	6.4516	0.8097
Gm. Cu. per amp hr.	1.177	0.0708	Cu. cm. in cu. inch.....	16.387	1.2145
Watts in H P.	746	2.8727	Gm. in ounce avoird.....	28,350	0.4526
Foot lbs in H P.	33000	4.5185	Lbs. in kilogram.....	2.2046	0.3433

MATHEMATICAL TABLES

TABLE OF SINES AND COSINES.

Sine °	Cos 60' 0' Sin	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Cos 0' 60' Sin	Cos °	Dif.
0	0000	0029	0058	0087	0116	0145	0174	89	29
1	0174	0204	0233	0262	0291	0320	0349	88	29
2	0349	0378	0407	0436	0465	0494	0523	87	29
3	0523	0552	0581	0610	0639	0668	0698	86	29
4	0698	0727	0756	0785	0814	0843	0872	85	29
5	0872	0900	0929	0958	0987	1016	1045	84	29
6	1045	1074	1103	1132	1161	1190	1219	83	29
7	1219	1248	1276	1305	1334	1363	1392	82	29
8	1392	1420	1449	1478	1507	1536	1564	81	29
9	1564	1593	1622	1650	1679	1708	1736	80	29
10	1736	1765	1794	1822	1851	1879	1908	79	29
11	1908	1937	1965	1994	2022	2051	2079	78	29
12	2079	2108	2136	2164	2193	2221	2249	77	28
13	2249	2278	2306	2334	2363	2391	2419	76	28
14	2419	2447	2476	2504	2532	2560	2588	75	28
15	2588	2616	2644	2672	2700	2728	2756	74	28
16	2756	2784	2812	2840	2868	2896	2924	73	28
17	2924	2951	2979	3007	3035	3062	3090	72	28
18	3090	3118	3145	3173	3201	3228	3256	71	28
19	3256	3283	3310	3338	3365	3393	3420	70	27
20	3420	3447	3475	3502	3529	3556	3584	69	27
21	3584	3611	3638	3665	3692	3719	3746	68	27
22	3746	3773	3800	3827	3854	3880	3907	67	27
23	3907	3934	3961	3987	4014	4041	4067	66	27
24	4067	4094	4120	4147	4173	4200	4226	65	27
25	4226	4252	4279	4305	4331	4357	4384	64	26
26	4384	4410	4436	4462	4488	4514	4540	63	26
27	4540	4566	4592	4617	4643	4669	4695	62	26
28	4695	4720	4746	4772	4797	4823	4848	61	26
29	4848	4873	4899	4924	4949	4975	5000	60	25
30	5000	5025	5050	5075	5100	5125	5150	59	25
31	5150	5175	5200	5225	5250	5274	5299	58	25
32	5299	5324	5348	5373	5397	5422	5446	57	25
33	5446	5471	5495	5519	5544	5568	5592	56	24
34	5592	5616	5640	5664	5688	5712	5736	55	24
35	5736	5760	5783	5807	5831	5854	5878	54	24
36	5878	5901	5925	5948	5972	5995	6018	53	23
37	6018	6041	6064	6088	6111	6134	6157	52	23
38	6157	6179	6202	6225	6248	6271	6293	51	23
39	6293	6316	6338	6361	6383	6406	6428	50	23
40	6428	6450	6472	6494	6517	6539	6561	49	22
41	6561	6582	6604	6626	6648	6670	6691	48	22
42	6691	6713	6734	6756	6777	6799	6820	47	22
43	6820	6841	6862	6883	6905	6926	6947	46	21
44	6947	6967	6988	7009	7030	7050	7071	45	21
45	7071	7092	7112	7132	7153	7173	7193	44	20
° Sine	Cos 60' 0' Sin	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Cos 0' 60' Sin	° Cos	Dif.

TABLE OF SINES AND COSINES.

Sine °	Cos. 60' 0' Sin.	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Cos. 0' 60' Sin.	Cos. °	Dif.
45	7071	7092	7112	7132	7153	7173	7193	44	20
46	7193	7214	7234	7254	7274	7294	7313	43	20
47	7313	7333	7353	7373	7392	7412	7431	42	20
48	7431	7451	7470	7490	7509	7528	7547	41	19
49	7547	7566	7585	7604	7623	7642	7660	40	19
50	7660	7679	7698	7716	7735	7753	7771	39	18
51	7771	7790	7808	7826	7844	7862	7880	38	18
52	7880	7898	7916	7933	7951	7969	7986	37	18
53	7986	8004	8021	8039	8056	8073	8090	36	17
54	8090	8107	8124	8141	8158	8175	8191	35	17
55	8191	8208	8225	8241	8258	8274	8290	34	17
56	8290	8307	8323	8339	8355	8371	8387	33	16
57	8387	8402	8418	8434	8449	8465	8480	32	16
58	8480	8496	8511	8526	8542	8557	8572	31	15
59	8572	8587	8601	8616	8631	8646	8660	30	15
60	8660	8675	8689	8704	8718	8732	8746	29	14
61	8746	8760	8774	8788	8802	8816	8829	28	14
62	8829	8843	8857	8870	8883	8897	8910	27	13
63	8910	8923	8936	8949	8962	8975	8988	26	13
64	8988	9001	9013	9026	9038	9051	9063	25	12
65	9063	9075	9087	9100	9112	9124	9135	24	12
66	9135	9147	9159	9171	9182	9194	9205	23	12
67	9205	9216	9228	9239	9250	9261	9272	22	11
68	9272	9283	9293	9304	9315	9325	9336	21	11
69	9336	9346	9356	9367	9377	9387	9397	20	10
70	9397	9407	9417	9426	9436	9446	9455	19	10
71	9455	9465	9474	9483	9492	9501	9511	18	09
72	9511	9519	9528	9537	9546	9554	9563	17	09
73	9563	9571	9580	9588	9596	9605	9613	16	08
74	9613	9621	9628	9636	9644	9652	9659	15	08
75	9659	9667	9674	9681	9689	9696	9703	14	07
76	9703	9710	9717	9724	9730	9737	9744	13	07
77	9744	9750	9757	9763	9769	9775	9781	12	06
78	9781	9787	9793	9799	9805	9811	9816	11	06
79	9816	9822	9827	9832	9838	9843	9848	10	05
80	9848	9853	9858	9863	9868	9872	9877	9	05
81	9877	9881	9886	9890	9894	9899	9903	8	04
82	9903	9907	9911	9914	9918	9922	9925	7	04
83	9925	9929	9932	9936	9939	9942	9945	6	03
84	9945	9948	9951	9954	9957	9959	9962	5	03
85	9962	9964	9967	9969	9971	9974	9976	4	02
86	9976	9978	9979	9981	9983	9985	9986	3	02
87	9986	9988	9989	9990	9992	9993	9994	2	01
88	9994	9995	9996	9997	9997	9998	9998	1	01
89	9998	9999	9999	0000	0000	0000	0000	0	00
° Sine	Cos. 60' 0' Sin.	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Co.s. 0' 60' Sin.	° Cos.	Dif.

TABLE OF TANGENTS AND COTANGENTS.

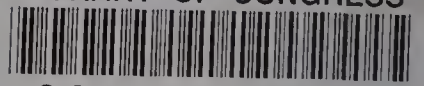
Tang. °	Cot. 60' 0' Tan.	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Cot. 0' 60' Tan.	Cot. °	Dif.
0	0000	0029	0058	0087	0116	0145	0175	89	29-29
1	0175	0204	0233	0262	0291	0320	0349	88	29-29
2	0349	0378	0407	0437	0466	0495	0524	87	29-29
3	0524	0553	0582	0612	0641	0670	0699	86	29-29
4	0699	0728	0758	0787	0816	0846	0875	85	29-29
5	0875	0904	0933	0963	0992	1022	1051	84	29-29
6	1051	1080	1110	1139	1169	1198	1228	83	29-29
7	1228	1257	1287	1316	1346	1376	1405	82	29-29
8	1405	1435	1465	1494	1524	1554	1584	81	30-30
9	1584	1614	1643	1673	1703	1733	1763	80	30-30
10	1763	1793	1823	1853	1883	1914	1944	79	30-30
11	1944	1974	2004	2034	2065	2095	2126	78	30-30
12	2126	2156	2186	2217	2247	2278	2309	77	30-30
13	2309	2339	2370	2401	2432	2462	2493	76	30-31
14	2493	2524	2555	2586	2617	2648	2679	75	31-31
15	2679	2711	2742	2773	2805	2836	2867	74	31-31
16	2867	2899	2930	2962	2994	3025	3057	73	32-32
17	3057	3089	3121	3153	3185	3217	3249	72	32-32
18	3249	3281	3314	3346	3378	3411	3443	71	32-32
19	3443	3476	3508	3541	3574	3607	3640	70	33-33
20	3640	3673	3706	3739	3772	3805	3839	69	33-34
21	3839	3872	3905	3939	3973	4006	4040	68	34-34
22	4040	4074	4108	4142	4176	4210	4245	67	34-35
23	4245	4279	4314	4348	4383	4417	4452	66	35-35
24	4452	4487	4522	4557	4592	4628	4663	65	35-35
25	4663	4698	4734	4770	4805	4841	4877	64	35-36
26	4877	4913	4949	4986	5022	5059	5095	63	36-36
27	5095	5132	5169	5206	5243	5280	5317	62	37-37
28	5317	5354	5392	5430	5467	5505	5543	61	37-38
29	5543	5581	5619	5658	5696	5735	5773	60	38-38
30	5773	5812	5851	5890	5930	5969	6009	59	39-40
31	6009	6048	6088	6128	6168	6208	6249	58	40-41
32	6249	6289	6330	6371	6412	6453	6494	57	41-41
33	6494	6535	6577	6619	6661	6703	6745	56	41-42
34	6745	6787	6830	6873	6916	6959	7002	55	42-43
35	7002	7045	7089	7133	7177	7221	7265	54	43-44
36	7265	7310	7355	7400	7445	7490	7535	53	45-45
37	7535	7581	7627	7673	7720	7766	7813	52	46-47
38	7813	7860	7907	7954	8002	8050	8098	51	47-48
39	8098	8146	8195	8243	8292	8341	8391	50	48-50
40	8391	8441	8491	8541	8591	8642	8693	49	50-51
41	8693	8744	8795	8847	8899	8951	9004	48	51-53
42	9004	9057	9110	9163	9217	9271	9325	47	53-54
43	9325	9380	9434	9490	9545	9601	9657	46	55-56
44	9657	9713	9770	9827	9884	9942	1.0000	45	56-58
45	1.0000	1.0053	1.0117	1.0176	1.0235	1.0295	1.0355	44	58-60
° Tang.	Cot. 60' 0' Tan.	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Cot. 0' 60' Tan.	° Cot.	Dif.

TABLE OF TANGENTS AND COTANGENTS.

Tan. °	Cot. 60' 0' Tan.	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Cot. 0' 60' Tan.	Cot °	Dif.
45	1.000	1.006	1.012	1.018	1.024	1.030	1.036	44	.006-.006
46	1.036	1.042	1.048	1.054	1.060	1.066	1.072	43	.006-.006
47	1.072	1.079	1.085	1.091	1.098	1.104	1.111	42	.007-.007
48	1.111	1.117	1.124	1.130	1.137	1.144	1.150	41	.007-.007
49	1.150	1.157	1.164	1.171	1.178	1.185	1.192	40	.007-.007
50	1.192	1.199	1.206	1.213	1.220	1.228	1.235	39	.007-.007
51	1.235	1.242	1.250	1.257	1.265	1.272	1.280	38	.007-.008
52	1.280	1.288	1.295	1.303	1.311	1.319	1.327	37	.008-.008
53	1.327	1.335	1.343	1.351	1.360	1.368	1.376	36	.008-.008
54	1.376	1.385	1.393	1.402	1.411	1.419	1.428	35	.009-.009
55	1.428	1.437	1.446	1.455	1.464	1.473	1.483	34	.009-.010
56	1.483	1.492	1.501	1.511	1.520	1.530	1.540	33	.009-.010
57	1.540	1.550	1.560	1.570	1.580	1.590	1.600	32	.010-.010
58	1.600	1.611	1.621	1.632	1.643	1.653	1.664	31	.011-.011
59	1.664	1.675	1.686	1.698	1.709	1.720	1.732	30	.011-.012
60	1.732	1.744	1.756	1.767	1.780	1.792	1.804	29	.012-.012
61	1.804	1.816	1.829	1.842	1.855	1.868	1.881	28	.012-.013
62	1.881	1.894	1.907	1.921	1.935	1.949	1.963	27	.014-.014
63	1.963	1.977	1.991	2.006	2.020	2.035	2.050	26	.014-.015
64	2.050	2.065	2.081	2.097	2.112	2.128	2.145	25	.015-.016
65	2.145	2.161	2.177	2.194	2.211	2.229	2.246	24	.016-.017
66	2.246	2.264	2.282	2.300	2.318	2.337	2.356	23	.018-.019
67	2.356	2.375	2.394	2.414	2.434	2.455	2.475	22	.019-.021
68	2.475	2.496	2.517	2.539	2.560	2.583	2.605	21	.021-.022
69	2.605	2.628	2.651	2.675	2.699	2.723	2.747	20	.023-.024
70	2.747	2.773	2.798	2.824	2.850	2.877	2.904	19	.025-.027
71	2.904	2.932	2.960	2.989	3.018	3.047	3.078	18	.028-.031
72	3.078	3.108	3.140	3.172	3.204	3.237	3.271	17	.031-.034
73	3.271	3.305	3.340	3.376	3.412	3.450	3.487	16	.034-.038
74	3.487	3.526	3.566	3.606	3.647	3.689	3.732	15	.039-.043
75	3.732	3.776	3.821	3.867	3.914	3.962	4.011	14	.044-.049
76	4.011	4.061	4.113	4.165	4.219	4.275	4.332	13	.050-.057
77	4.332	4.390	4.449	4.511	4.574	4.638	4.705	12	.058-.067
78	4.705	4.773	4.843	4.915	4.989	5.066	5.145	11	.068-.079
79	5.145	5.226	5.309	5.396	5.484	5.576	5.671	10	.081-.095
80	5.671	5.769	5.871	5.976	6.084	6.197	6.314	9	.098-.107
81	6.314	6.435	6.561	6.691	6.827	6.968	7.115	8	.121-.147
82	7.115	7.269	7.429	7.596	7.770	7.953	8.144	7	.154-.191
83	8.144	8.345	8.556	8.777	9.010	9.255	9.514	6	.231-.259
84	9.514	9.788	10.08	10.39	10.71	11.06	11.43	5	.274-.37
85	11.43	11.83	12.25	12.71	13.20	13.73	14.30	4	.40 -.57
86	14.30	14.92	15.60	16.35	17.17	18.07	19.08	3	.62 -1.01
87	19.08	20.21	21.47	22.90	24.54	26.43	28.64	2	1.13 -2.21
88	28.64	31.24	34.37	38.19	42.96	49.10	57.29	1	2.60 -8.19
89	57.29	68.75	85.94	114.6	171.9	343.8	∞	0	11.46-∞
° Tan.	Cot. 60' 0' Tan.	50' 10'	40' 20'	30' 30'	20' 40'	10' 50'	Cot. 0' 60' Tan.	° Cot	Dif.

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